Democracy, Dictatorship and Technological Change

Carl Henrik Knutsen

Department of Political Science, University of Oslo

Contact: c.h.knutsen@stv.uio.no

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Abstract

This paper investigates how regime type affects technological change, arguably the most important determinant of long term economic growth. The paper's main hypothesis is that democracies have higher technology-induced economic growth than dictatorships. This hypothesis is deduced from a formal model where dictators are assumed to value both personal consumption and staying in office. In the model, dictators can restrict civil liberties and diffusion of information, which reduces economic growth, but increases dictators' probability of surviving in office. The model also implies that dictators enforce harsher restrictions on civil liberties if the global rate of technological change is low, if the capital shares of their economies are high, if their ability to discern politically dangerous from economically relevant information is poor, and if their positions in office are insecure. The hypothesis that democracies have higher technology-induced growth is tested on an extensive dataset, including data from more than 100 countries with some time series going back to the 19th century. The hypothesis finds robust empirical support: Democracies produce higher Total Factor Productivity growth than dictatorships. The paper also discusses the hypothesis that dictatorships with high bureaucratic quality can mitigate democracies' advantage in generating technological change. This hypothesis finds only partial support.

1 Introduction

This paper investigates how democracy and dictatorship affect technological change. The literature on democracy's economic effects, both theoretical and empirical, has mostly focused on how democracy affects growth through physical capital- (see e.g. Przeworski and Limongi 1993; Tavares and Wacziarg 2001) and human capital accumulation (see e.g. Baum and Lake 2003; Stasavage 2005).[1] In the economic growth literature however, technological change is generally viewed as *the* central determinant of long run growth (see e.g. Solow 1957; Nelson and Winter 1982; Romer 1990; Aghion and Howitt 1992; Grossman and Helpman 1991; Klenow and Rodriguez-Clare 1997; Helpman 2004; Nelson 2005) (but see Mankiw, Romer and Weil 1992). Even if there is only a weak effect from democracy on technological change, this may be very important for development over time, given the importance of technological change for long-run economic growth. Technological change is not exogenous, as new growth economists (e.g. Romer 1990; Aghion and Howitt 1992) and evolutionary economists (e.g. Verspagen 2005; Nelson 2005) have recognized. Technological change is among others endogenous to institutional factors. However, growth theory has mostly focused on economic institutional factors like business-structures and patent rights and economic policies related to for example interest rates. However, as political economists recognize, economic institutions and policies are endogenous to deeper political structures, such as regime type (e.g. North 1990; Rodrik 2000). This paper argues that democracy affects the dissemination of ideas and technologies into and within an economy, thus affecting technological change.

More specifically, this paper presents a model that shows how self-interested dictators may restrict civil liberties for political survival purposes. In an imperfect world where dictators can not fine-tune policies so that all political dangerous information is blocked and all

[1] There are some exceptions. Przeworski et al. (2000) conducted growth accounting on data from 1950 to 1990, and their results indicated that democracies may do better on technological change, but only among rich countries. Pinto and Timmons (2005) also investigated the relationship, but relied on problematic proxies of technological change, like foreign direct investment and trade.

economically productive information allowed, such restrictive policies also inhibit dissemination of economically relevant ideas and technologies. Idea generation and diffusion require information, and the ability for people to communicate, discuss and learn freely without restrictions. Limitations on freedom of travel, media and speech delimit economic actors' ability to learn and adopt foreign and nationally developed ideas. The model also predicts that dictatorial regimes with better bureaucratic quality, or higher institutional capacity more generally, should mitigate democracy's technology advantage. The hypotheses from this model are tested, using Total Factor Productivity (TFP) data as a proxy for technological change. An extensive cross-country–time-series data set is used, with data going back to the 19th century for some countries. The empirical analysis corroborates the main hypothesis: Dictatorship reduces technological change relative to democracy. However, the hypothesis that dictatorships with higher institutional capacity are able to mitigate democracy's technological advantages, finds only weak support. Section 2 briefly presents earlier literature on technological change and economic growth. Section 3 discusses the assumptions underlying the formal model, and thereafter presents, solves and discusses the model. Section 4 presents the data and the methods. Section 5 presents the empirical analysis. Section 6 concludes.

2 Technological change and economic growth

Historically, macroeconomists emphasized accumulation of inputs as determinants of income and growth (Helpman 2004, :9), probably because technology was modeled as exogenous in influential growth-models such as Solow (1956). However Solow (1957) himself found that technological change contributed more than input accumulation to economic growth in the United States. This result was also established in for example Abramowitz (1956) and Denison (1962). Moreover, Denison (1968) found the same pattern for European countries. In later years, economists studying developing countries have argued that technological change is the key to growth also for poorer countries (e.g. Easterly 2001). Some, empirical estimates indicate that differences in technological efficiency explain the main bulk (about 9/10) of variation in income across countries globally (Klenow and Rodriguez-Clare 1997), whereas other estimates indicate a larger role for human capital (Mankiw, Romer and Weil 1992). The separation of growth due to human and physical capital accumulation and technology is not straightforward. For example, new technologies often come with new investments in machinery (Nelson 2005), and a high level of human capital may be conducive to the spread of more efficient technologies (Kremer 1993). Nevertheless, "there is convincing evidence that total factor productivity plays a major role in accounting for the observed cross-country variation in income per worker and patterns of economic growth" (Helpman 2004, :33).

Schumpeter (1976) highlighted the role of "creative destruction" for economic dynamism, with new techniques, products and even industries outcompeting older ones. Nelson and Winter (1982) developed models focusing on the roles of idea-variety and selection of more efficient ideas for economic growth. After Nelson and Winter followed several "evolutionary economic models" of technological change and economic growth (see e.g. Fagerberg 2003; Nelson 2005; Verspagen 2005). Also, Lucas (1988), Romer (1990), Aghion and Howitt (1992) and Grossman and Helpman (1991), modeled economic growth processes driven by knowledge and technological change. The models endogenized technological change, to show how technological change was determined by self-interested actors interacting within specific market structures and institutional environments. In Romer's model, profit-maximizing firms competing under imperfect competition put resources into research and development, thus contributing to technological change by providing a wider variety of new products. In Grossman and Helpman (1991) and Aghion and Howitt (1992) models, technological change is generated by firms investing in R&D to make improved products, thus outcompeting older products of inferior quality. Also economic historians have analyzed determinants of technological change and such change's impact on economic growth (see e.g. Mokyr 1990; Rosenberg 1982). Mokyr (2002) stressed the importance of scientific knowledge for the frequency with which new, practical applications appear in the marketplace. Others focused on so-called technological paradigms and "radical" innovations (see e.g. Verspagen 2005), also called general purpose technologies (Bresnahan and Trajtenberg 1995), for the development of new spin-off products and techniques. Examples are the steam engine, electricity and the computer.

Romer (1993) discussed the importance of open flows of ideas for economic growth. Much of the literature on economic convergence and development in poorer countries has focused on capital accumulation (Easterly 2001), but the impact of flows of new ideas can be immense. Ideas are non-rivalrous entities (Romer 1993); an idea can be used by several actors without diminishing its value for others. This characteristic contributes to the importance of technological change for global economic growth, as ideas in principle can be used freely to enhance efficiency in several places at the same time. Technological change thus not only contributes to growth in rich countries at the "technological frontier", but also in developing countries (Helpman 2004), as poorer countries can adopt technological (and organizational) improvements developed elsewhere. Understanding why some countries are better at adopting techniques, both related to production and organization, and diffusing them throughout their economies, is therefore crucial for understanding differences in income level and growth rates.

3 Theoretical discussion

In the model below, dictators restrict information flows in society by curbing civil liberties. This, in turn, reduces technological change. The dictator's reason for restricting civil liberties is increasing his probability of staying in power.[2] Before presenting the model, I expand on the role of civil liberties and open information flows for technological change.

3.1 Civil liberties, information flows and technological change

Technology, including ideas about efficient forms of economic organization (North 1990; Greif 1993), must be created nationally or adopted from abroad. Thereafter, it must diffuse throughout the economy to bring about technology-induced economic growth. A broad diversity of ideas generally improve economic efficiency, especially when economic actors easily learn of the new ideas and select the most efficient. A dynamic economy "is the outcome of a constant interaction between variety and selection" (Verspagen 2005, :496). Selection reduces variety since more efficient techniques are adopted through learning and drive out older, inefficient production methods. In order to keep up variety, the economy needs a continuous introduction of novel ideas. Civil liberties, such as freedom of speech, freedom of press, freedom of travel and other civil liberties allow for introduction of new ideas and idea diffusion into the wider economy. Civil liberties also allow for comparison of different ideas, thus allowing for the more efficient to win out. Civil liberties therefore enhance both variety and selection, as the introduction of new ideas, from abroad or from national entrepreneurs, but also learning processes, rely on the possibility of collecting and processing information in a fairly unrestricted manner.

Civil liberties are better protected in democracies than in dictatorships. Many theorists even argue that civil liberties are inherent properties of democracy (e.g. Beetham 1999; Inglehart and Welzel 2006). We would thus expect democracies to have higher long-run growth rates due to more rapid technological change. Open debate and free communication is important for introducing and diffusing new ideas. Also, evaluating and changing old ways of doing

[2] However, if the dictator can manipulate patent rights and university systems in a way that enhances his survival probability, but which reduces the rate of technological change, this is perfectly in line with the logic of the model.

things, thus achieving progress by trial and error, are important for economic dynamism. These characteristics are more prevalent in democracies. In other words, democracies "realize superior developmental performance because they tend to be more adaptable" (Halperin, Siegle and Weinstein 2005, :14). One version of this argument was presented already in John Stuart Mill's "On Liberty". Although Mill (1974) did not focus explicitly on economic efficiency, his arguments bear relevance also for technological change. Mill, discussing political suppression of ideas, noted that "the opinion which it is attempted to suppress by authority may possibly be true. Those who desire to suppress it, of course, deny its truth; but they are not infallible" (1974:77). With power concentration and limits to freedom of speech and press, people at the top of the hierarchy, because of limited knowledge or self-interest, may suppress ideas that are essentially correct. These ideas may be of both economic and political relevance.

Freedom of speech secures a wide variety of ideas, argued to be crucial for technological dynamism in the marketplace. But, variation and evaluation of ideas may be equally important when it comes to economic policies and organizational issues. As North (1990) note, economic efficiency improvements are not only generated by product innovations, but also by changes in economic institutions and organizations. Politicians and bureaucrats must receive information signals to provide efficient policies, for example when it comes to industrial policies (Evans 1995). The "dictator's dilemma" is a relevant insight (Mueller 2003, 416-7). Because of fear of falling out with the dictator or others in the regime, individuals and organizations might not be forthcoming with their most accurate information. This reduces the quality of information the regime draws upon when making decisions. Moreover, freedom of speech contributes to actors "assessing and disseminating ideas from abroad, discourages insular thinking and stimulates vigorous debate" (Halperin, Siegle and Weinstein 2005, :13). Restrictions on freedom of speech and media hurt efficiency, as important problems are not reported and alternative viewpoints on economic policies, organizational issues and different structural problems are not forthcoming to the political rulers, or maybe even the bureaucracy. This is likely to have implications for economic efficiency and even productivity growth.

North (2005) argues the inherent uncertainty about policy- and organizational effects necessitates a process of trial and error, with proper feedback from society on these effects. Open systems, associated with democratic government and civil liberties, are crucial for information flows that allow such efficiency enhancing trial and error- and feedback-processes. In other words, "open access orders more readily generate a range of solution to problems; they more readily experiment with solutions to problems; and they more readily discard ideas and leaders who fail to solve them" (North, Wallis and Weingast 2009, :134). The opportunity for actors outside the government to freely voice their opinion on political reforms therefore likely improves organizational and policy efficiency. (von Hayek 1944) arguments on utilization of decentralized knowledge was mainly focused on the relative benefits of price-based markets over central planning. However, his arguments bear relevance for civil liberties' effect on economic efficiency. As von Hayek argues, we must be attentive to "the unavoidable imperfection of man's knowledge and the consequent need for a process by which knowledge is constantly communicated and acquired" (1945:530). Different actors possess only partial knowledge about economic and political processes. Open debate and free idea flows are crucial for efficient decision-making by firms, bureaucrats and politicians, as "the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess" (von Hayek 1945, :519). Also North, Wallis and Weingast (2009), argue that open competition in both the economic and political spheres are crucial for adaptive efficiency: "Open access and free flow of ideas generate a range of potential ways to understand and resolve new problems . . . The free and open expression of ideas means that many ideas will be heard. In their quest to maintain or to regain power, competing parties will draw on this competition for solution"(pp. 133-134). The interaction of civil liberties and political competition among self-interested elite in "open access orders" generate an increased flow of ideas which enhances efficiency. This contrasts with dictatorships, where dictators seek to limit idea flows and the variety of ideas in order to retain power.[3]

3.2 Political economic models of self-interested leaders and inefficient policies

Why would dictators want to curb information flows if they are beneficial for economic growth? Generally, dictators may, because of preferences for private consumption or political survival, have incentives to take actions that have negative consequences for their national economies (e.g. Olson 1993; Robinson 2001; Bueno de Mesquita et al. 2003; Acemoglu and Robinson 2006). In Olson's (1993) model, dictators, especially those with short time horizons, expropriate property to maximize personal consumption, thereby reducing the incentives for citizens to work or invest. In Robinson's model (2001) and Acemoglu and Robinson's (2006) models, dictators also maximize discounted utility from consumption. In these models, public investment and economic development more generally, strengthen opposition groups and reduce leaders survival probability. Leaders may thus reduce the overall size of the economy, among others through manipulating public investment levels, to maximize expected utility from (discounted) private consumption. Bueno de Mesquita et al.'s (2003) model assumes that political leaders are interested in surviving in office, and shows

[3]Another mechanism may contribute to a positive effect from democracy on technological change: To Mill, the stifling of debate and the intellectual conformism that followed restrictions in freedom of speech could have far-reaching consequences, as "the price paid for such intellectual pacification is the sacrifice of the entire moral courage of human mind" (1974:94). Restrictions on freedom of speech leads to an environment where conform behavior dominates, and where new thoughts, alternative ways of doing things and experimentation suffer. This again impacts negatively on invention, technological innovation and economic dynamism. Psychological-experimental studies could investigate whether this mechanism is relevant, for example by studying the creativity of individuals in different environments.

how dictators, especially those with small winning coalitions and large selectorates, underinvest in growth-conducive public goods. For these leaders, it is rational to expropriate or tax heavily and redistribute resources as private goods to their relatively small winning coalitions. Another relevant model comes from Wintrobe (1990). In this model, certain power-motivated dictators overinvest in repressive capacity. Investment in a repressive apparatus distorts public resources away from more productive projects, thus hurting economic efficiency.

3.3 A political economic model of information flows and technological change

The model presented here draws on the general logic of the political economic models above: The model shows how dictators have incentives to conduct policies that are beneficial for their own interest but hurtful for the overall economy. The model presented here is fairly simple, and simpler than those above, since the focus here is relatively specific; the model shows how dictators have incentives for restricting information flows, thus crippling diffusion of technology. One main assumption is that civil liberties generate better access for economic actors to new and alternative domestic and international ideas. The model thus focuses on political institutional characteristics that "frame the struggle between the proponents of change and their opponents, and thereby affect the ability of countries to innovate and to implement new technologies" (Helpman 2004, :112).

3.3.1 The economy

We assume an adjusted neo-classical production function, as in (Mankiw, Romer and Weil 1992): $Y = F(TL, K, H)$, where Y is output, T technology level, L labor input, K physical capital input and H human capital input. F is increasing, but concave, in all inputs. $\frac{\partial Y}{\partial T} =$

$L \cdot \frac{\partial F}{\partial TL} > 0$: As technological efficiency increases, so does output. For simplicity, let us assume a Cobb-Douglass production function, as in Mankiw, Romer and Weil (1992):

$$Y = F(K, L, H, T) = K^{\alpha} H^{\beta} (TL)^{1-\alpha-\beta}. \tag{1}$$

Technology is, however, here treated as endogenous. But, the endogeneity is quite simple. This model does not look into incentives for firms to generate new technology as the advanced models of "new growth theory" (Romer 1990; Grossman and Helpman 1991; Aghion and Howitt 1992); it simply assumes that technology level in a country depends on information and idea-flows into and within the country. Generation of cutting-edge technology in increasing-returns-to-scale sectors, as modeled in new growth theory, is mostly relevant for relatively large and rich developed countries. However, for most countries the global technological frontier is largely exogenous, and the diffusion (and local adaptation) of international technology is key for technological efficiency. Thus, one can focus on models of technology diffusion when studying cross-country differences in technology-induced economic growth.

Here, technology, T, is a function of information flow, i. Information flows are assumed to come in two pure types, politically relevant and economically relevant information, i_e and i_p. However, there is also non-pure information, i_{ep}, which is of both economic and political relevance. T is a function of i_e and i_{ep}, but not i_p. We assume that not only level, but also rate of change in technology, $\frac{\dot{T}}{T}$, is a function of i_e and i_{ep}; information flows are crucial for the degree to which new global techniques and ideas are adopted. One straightforward way of modeling this is to assume that a number of new techniques, A_t^* , where t denotes year, is developed globally each year, thus constituting annual contribution to the global technology frontier. This frontier is here treated as exogenous. Technological change is determined by how many of the new techniques economic actors in a country are able to adopt, A_t. Therefore, $\frac{\dot{T}}{T} = \omega(A_t)$.

A_t is a function of A^*_t , i_e and i_{ep}. We normalize so that $i_e + i_{ep}$ varies between 0 and 1, with 0 indicating a country that restricts all economic information flows and 1 indicating a country that allows for the free flow of economic information. We assume, in the simplest of models, that $A_t = (i_e + i_{ep})A^*_t$. This means that

$$\frac{\dot{T}}{T} = \omega((i_e + i_{ep})A^*_t). \tag{2}$$

It can be shown, through taking logarithms and differentiating the production function, that

$$\frac{\dot{Y}}{Y} = (1-\alpha-\beta)\frac{\dot{T}}{T} + \alpha\frac{\dot{K}}{K} + \beta\frac{\dot{H}}{H} + (1-\alpha-\beta)\frac{\dot{L}}{L} \tag{3}$$

This again implies that

$$\frac{\dot{Y}}{Y} = (1-\alpha-\beta)\omega((i_e + i_{ep})A^*_t) + \alpha\frac{\dot{K}}{K} + \beta\frac{\dot{H}}{H} + (1-\alpha-\beta)\frac{\dot{L}}{L} \tag{4}$$

Equation 4 shows that GDP growth rates depend on growth rates of capital, human capital and labor, changes in the global technological frontier and the information flows in national economies. If countries are in their steady states (see e.g. Barro and Sala-i Martin 2004), income in countries with free information flows will grow with the rate of change in the global technology frontier. If information flows are only restricted by curbing of civil liberties, all "perfect democracies" will according to the model grow as fast as the global technology frontier in steady state. However, in other regimes, steady state growth rates will be weighted down with a factor related to degree of information flow-restrictions. A country where almost no information is allowed, North Korea could be a suitable empirical example (see e.g. Kihl and Kim 2006), will have very low long-run (steady state) growth rates. This model therefore not only predicts income level-divergence, but also in income growth-divergence. Democratic economies will not only be richer, but also grow at higher rates than dictatorial.

3.3.2 Political decision making

Let us endogenize the political decision to restrict information flows. First, we simply assume that in democracies, all types of information are allowed.[4] Let us therefore consider a dictator, D, in a two-period model, who maximizes a utility function dependent on both personal consumption, and political survival in the second period. $U = U(c, q)$, where c is consumption and q is survival probability. $U(c, q)$ is increasing and concave in both arguments. D receives a fixed share, λ, of total economic output, and therefore, ceteris paribus, wants to increase the economy's size to increase personal consumption. D's consumption is given by

$$c_t \leq \lambda Y_t = \lambda K_t^\alpha H_t^\beta (T_t L_t)^{1-\alpha-\beta} \tag{5}$$

Since there is no saving in the model and $U'(c) > 0$, Inequality 5 will hold with equality. We manipulate the utility function, to analyze the dictators preferences for consumption growth rates instead of levels. We assume an exogenously given Y_0, and thus c_0, in period 0, before the model's action starts. Change in consumption, Δc, is therefore given by

$$\Delta c_t = c_t - c_0 = \lambda K_t^\alpha H_t^\beta (T_t L_t)^{1-\alpha-\beta} - \lambda K_0^\alpha H_0^\beta (T_0 L_0)^{1-\alpha-\beta} \tag{6}$$

For simplicity, and without loss of generality, we can assume that $K_t = K_0$, $H_t = H_0$, $L_t = L_0$, so that Δc is only a function of changes in T. Further, if we use the equation for growth rates in GDP, we find that D's consumption growth rate $\frac{\dot{c}}{c} = \frac{\Delta c}{c_0}$, denoted g_c, is given

[4] Although this is not necessarily true, the assumption could be weakened to an assumption that democratic leaders restrict civil liberties less than dictators.

by

$$g_c = (1 - \alpha - \beta)\omega((i_e + i_{ep})A_t^*) \tag{7}$$

if we hold λ constant.

Since c_0 is exogenous, and $U'(c) > 0$, $U'(\Delta c)$, and therefore $U'(g_c)$ must also be > 0.

D starts out in power and sets policy $(i_e; i_p; i_{ep})$ in the first period. D has a probability $(1-q)$ of losing power in the second period. Before the revelation of whether D loses power or not, he receives his income which is used for consumption. We assume that D consumes, whether he loses power or not. D could for example, transfer his resources to a foreign bank account, and move into exile if ousted. We will discuss this assumption more closely below. The probability of staying in power, q, is endogenous to the policy parameters, the information flows allowed. We can think of information flow being affected by policies such as restrictions on freedom of speech, freedom of media, communication policy for example towards usage of cell phones, freedom of travel within and outside the country, openness towards foreign visitors and ideas, etc. These are the actual policies set by D, but we model their consequence, i, as the choice variable to simplify. More specifically, the probability of dictatorial survival is decreasing in i_p and i_{ep}, but is unaffected by i_e. That is $\frac{\partial q}{\partial i_p} < 0$, $\frac{\partial q}{\partial i_{ep}} < 0$ and $\frac{\partial q}{\partial i_e} = 0$. We model the relationship with the simple, linear function:

$$q = (1 - (\gamma i_p + \eta i_{ep})) \tag{8}$$

Here, $\gamma > 0$, $\eta > 0$ and $0 \leq \gamma i_p + \eta i_{ep} \leq 1$. This implies that the probability of survival varies between 1 when no political and mixed political-economic information is allowed to flow in society by the dictator, and 0, which results from a high level of political and/or mixed political-economic information flow. If $\gamma = \eta$, i_p and i_{ep} information are equally dangerous to the dictator. Generally, it is difficult for dictatorial governments to screen each and every act of communication, travel and meeting, and governments therefore need to establish some general rules. Therefore, information activities are banned under uncertainty of their contents, and such information is often of i_{ep} type. General restrictions on civil liberties will not only reduce political communication, but also economically relevant communication. Thus, disallowing general free and open exchange of information and debate will have effects not only in terms of stifling political opposition, but also economic dynamism. One way to model the relationships between q and i_p and i_{ep} more thoroughly would be to assume an opposition consisting of several individuals, all desiring to overthrow D. The probability of the opposition being able to overthrow D, $(1-q)$, depends on coordination abilities. If one individual attempted to overthrow D, $(1-q)$ would be small. But, as collective action problems are solved and opposition-members coordinate, $(1-q)$ increases. The ability of the opposition to coordinate depends on their ability to use communication tools, assemble without harassment or detention, gain access to media and travel freely in the country. Therefore, restrictions on civil liberties that reduce politically relevant information flows, i_p and i_{ep}, reduce the opposition's ability to coordinate and thus $(1-q)$.

Let us return to D's transformed utility function, $U(g_c, q)$. If we insert for Equations 7 and 8, we get:

$$U(g_c, q) = U((1-\alpha-\beta)\omega((i_e + i_{ep})A_t^*), (1-(\gamma i_p + \eta i_{ep}))) \tag{9}$$

One may immediately see from Equation 9 that D minimizes i_p and maximizes i_e. D cracks down on all information flows that are politically dangerous for him but are irrelevant for economic efficiency, and opens up for information that only improves economic efficiency but is irrelevant for his political survival. We can show this more stringently by taking the first-order derivatives of U with respect to i_p and i_e:

$$\frac{\partial U}{\partial i_p} = -\gamma \frac{\partial U}{\partial q} \tag{10}$$

$$\frac{\partial U}{\partial i_e} = \frac{\partial U}{\partial g_c} \cdot (1-\alpha-\beta)A_t^*\omega'(A_t) \tag{11}$$

Equations 10 and 11 show it is always rational for the dictator to increase i_e, as $\frac{\partial U}{\partial i_e} > 0$ and reduce i_p as $\frac{\partial U}{\partial i_p} < 0$. Thereby i_e and i_p will be set at their maximum and minimum levels respectively. The interesting trade-off in the model relates to i_{ep}. D on the one hand wants to allow i_{ep} because it increases efficiency and thus private consumption growth. But, on the other, he wants to restrict i_{ep} because it puts his political survival at risk. We calculate the marginal effect from i_{ep} on D's utility. The first-order condition is given by:

$$\frac{\partial U}{\partial i_{ep}} = \frac{\partial U}{\partial g_c} \cdot (1-\alpha-\beta)A_t^*\omega'(A_t) - \eta\frac{\partial U}{\partial q} \tag{12}$$

Since in optimum $\frac{\partial U}{\partial i_{ep}} = 0$, Equation 12 implies that the dictator will set i_{ep}, so that:

$$\frac{\partial U}{\partial g_c} \cdot (1-\alpha-\beta)A_t^*\omega'(A_t) = \eta\frac{\partial U}{\partial q} \tag{13}$$

[5]

Equation 13 shows that in optimum, the dictator will balance increase in marginal utility from consumption against the expected marginal utility-decrease from reduced survival probability, when setting i_{ep}. Thus, some i_{ep} is restricted in dictatorships, whereas all i_{ep} is allowed in democracies. We therefore have that:

Proposition 1 *Democracies will experience more rapid technological change than dictatorships.*

Since we assumed that the utility was increasing and concave in the two arguments, we see from Equation 12 that the optimal amount of i_{ep} decreases in α and β, the capital and human capital shares of the economy. In other words, when technological change plays an

[5]This can be rewritten in marginal rate of substitution form to $\frac{\frac{\partial U}{\partial g_c}}{\frac{\partial U}{\partial q}} = \frac{\eta}{(1-\alpha-\beta)A_t^*\omega'(A_t)}$.

important role in producing growth, relative to input accumulation, the model predicts less restriction on information and thus less violation of civil liberties.

Proposition 2 *The higher the physical and human capital shares are in a country's production processes, the larger will the difference in civil liberties protection, and steady-state growth rates, between democracies and dictatorships be.*

Optimum i_{ep} also increases with $\omega'(A_t)$, which implies that an economy where adopting new ideas is more important for TFP-growth will set a higher level of i_{ep}, quite naturally. The optimal amount of i_{ep} also increases with the global technology frontier's growth rate, as $\frac{\partial U}{\partial i_{ep}}$ depends positively on A_t^*: It is rational for D, because of personal consumption reasons, to open up for more information when the world's leading economies are generating more new technology. One empirical implication is thus that dictators will loosen restrictions on civil liberties in periods with high global growth rates.

Proposition 3 *Dictators will loosen restrictions on civil liberties in times of rapid technological change globally, and thus absorb a higher share of new global ideas.*

However, the optimal i_{ep} decreases when η increases. η reflects how strongly the flow of i_{ep} affects D's survival probability. If D is relatively insensitive to such information flows, for example because of high legitimacy, weak opposition or existence of an efficient repression apparatus, D will allow more i_{ep}. A dictator with safe grip on power can allow more i_{ep} to increase personal consumption.

Proposition 4 *When a dictator has a safe grip on power because of exogenous reasons, dictatorships will experience higher rates of technological change and less restrictions on civil liberties.*

The optimality condition in Equation 13 holds if the dictator realizes consumption before it is decided whether he keeps or looses office. If we alter the sequence and let the possible realization of a revolution or coup happen before the dictator's consumption, D would have extra incentives to curb civil liberties because expected value of consumption for a given i_{ep} is reduced; D receives no consumption with a probability $1 - q$. We could have used this sequence and assumed that dictators were only interested in consumption, and not office for its own sake. This would bring the model's logic closer to those of Robinson (2001) and Acemoglu and Robinson (2006). In these models, rulers conduct inefficient policies because they increase future expected private consumption through reducing the probability of being thrown out of office; but, office in itself has no value. The models' main result, lower technological change in dictatorships, is therefore relatively insensitive to the assumptions of rulers' motivation. However, if the ruler is both interested in consumption and office *and* a potential revolution wipes out the ruler's earnings, the incentives for inefficient policies are the strongest. Compared to this situation, leaders only interested in consumption, or office- and consumption motivated leaders who can hide away resources in foreign banks, provide relatively more efficient policies.

Proposition 5 *Rulers that are motivated both by office and personal consumption will reduce technological change more than rulers only motivated by consumption.*

Proposition 6 *Rulers that are able to consume wealth earned while in office, after they are deposed, will reduce technological change less than leaders who are unable to consume such earnings.*

Evans (1995) analyzed the importance of public-private informational linkages for policy decisions, bureaucrats' ability to implement policies efficiently and the ability for private and public actors to cooperate. One important aspect in this regard is informational feedback on public policies. Although dictatorships in general are likely outperformed by democracies on this dimension, as discussed above, some dictatorships may be better able than others to mitigate informational problems. Even with limitations on freedom of speech and press, some dictatorships may perform adequately because of better abilities for absorbing and interpreting weak information signals. This ability is likely related to the quality of the bureaucracy, and the capacity of state institutions more in general. Dictatorships with better bureaucratic and institutional qualities may also be better able to design policies that enable separation of politically and economically relevant information. For example, a high-quality bureaucracy may be able to fine-tune its internet policies so that only politically problematic pages are blocked. In terms of the model i_{ep}, decreases as bureaucratic quality, b, increases, that is: $i_{ep} = i_{ep}(b)$, where $i'_{ep}(b) < 0$. As $i_e + i_{ep} = 1$, $i'_e(b) > 0$. In democracies, where all information, also all i_{ep}, is allowed, b will not matter for technological change. As restrictions on civil liberties are put in place however, b will matter for technological change, as i_{ep} is restricted under such systems. A high b will allow dictatorial regimes to separate better between politically and economically relevant information. As i_e is always allowed by the dictator, a high b will increase technological change in dictatorships. In a hypothetical case where the bureaucracy is able to perfectly separate between political and economic information, and i_{ep} is zero, democracies and dictatorships will have equal rates of technological change, even if dictatorships ban all politically relevant information.

Proposition 7 *Dictatorships with higher institutional capacity will have higher rates of technological change than dictatorships with lower institutional capacity.*

3.3.3 Discussion

Open diffusion and use of technologies can in principle coexist with limited political debate. However, this is difficult in practice. Good examples are related to modern communication technologies, like the cell phone and the Internet. Hachigian recognizes the dictator's conundrum presented in this paper: "The Internet presents a dilemma to leaders of authoritarian states and illiberal democracies. It promises enticing commercial advantages, such as transaction cost reductions, e-commerce possibilities, and foreign trade facilitation. Yet, by giving citizens access to outside information and platforms for discussion and organization, the Internet can also help politically empower populations and potentially threaten regimes" (Hachigian 2002, :41). Hachigian indicates that different regimes have struck different balances regarding Internet policies. The expectation from the model above is that regimes with relatively high institutional capacity, like China, would pursue a more refined and differentiated approach than for example a country like Uzbekistan, which would be less able to filter politically from economically relevant information. Cell-phone technology also present both political problems and potential economic gains to dictators. Bans on cell-phones have been imposed in Cuba and Turkmenistan, for example, as these are dangerous coordination devices for political opposition. However, restrictions on phone communication also cripple the efficiency of businesses. Freedom of travel, into and out of a country, may also be restricted because of political reasons. North Korea is one example; even travel into Pyongyang is restricted for North Koreans. Although strict regulation of international travel may enhance political survival, it severely affects North Koreans' ability to learn new and productive foreign technologies.

Another, and more curious example, comes from the Soviet Union, where the Polit-bureau banned foreign economics journals, which were seen as spreading potentially dangerous ideas in opposition with the governing ideology (Greenspan 2007). However, econometric journals were allowed, probably because they were seen as less politically dangerous: The Polit-bureau tried to separate between i_e and i_{ep} information. More generally, although there were debates in the 1930s and 40s on the relative efficiency of price-based markets versus central planning, historical experiences, especially from the 1970s onward, showed that central planning was statically and dynamically inefficient. A more open political system than the Soviet would perhaps have experienced intense debates among the elites and the population on how to pursue efficiency-enhancing policy reform. Ironically, when Gorbatschev at last opened up the political and economic sphere, it arguably contributed to the regime's downfall some years later, illustrating another main point of the model: Allowing information flows in a dictatorship is dangerous for regime survival.

Another dictatorial regime generating technological and economic stagnation was imperial China. China experienced a dramatic relative economic decline compared to Western Europe, especially from the 19th century (see e.g. Landes 2003). The Chinese empire was characterized by the ruling dynasty's concentration of power and its closed nature, in terms of foreign relations. Political rulers neglected and even outlawed new and more effective organization techniques and production technologies. Especially foreign ideas were espoused. A letter from Emperor Ch'ien Lung to George III of England in 1793, who wanted to trade with the Chinese, illustrates that dictatorship can be obstructive to adaptation of foreign ideas: When denying the British overtures, the Chinese Emperor wrote that the "Celestial Empire possesses all things in abundance. We have no need for barbarian products" (Ch'ien Lung cited in Murphey Murphey 2000, :245). According to Landes, "even the obvious lead of Western technology in the modern period was insufficient to disabuse them of this crippling self-sufficiency" (2003:28). The leaders' desires for technological and economic self-sufficiency would likely not have been as crippling to the economy had society been more pluralistic. Within a more open society, new technologies and organizational ideas could have found foothold somewhere in the economy, although its rulers despised them. If much more efficient, these technologies would likely win out in the longer run. However, Chinese dealing with foreigners and their ideas, in this authoritarian society "always ran the risk of being denounced, or worse, as a traitor" (Landes 2003, :28). It is likely that consecutive Chinese Emperors shut out Western ideas because they undermined the legitimacy and power of the Quing-dynasty (REFERENCE REMOVED).[6]

[6] Another interesting observation is that the dictatorships with greatest economic success after WWII, South Korea, Taiwan and Singapore, have not had very high rates of TFP-growth (Young, 1995): Technology, the main driver of economic growth in most OECD countries after WWII, was not the main source of these Tigers' growth. Instead, accumulation of physical and human capital and mobilization of labor were the main sources of growth. Singapore is the most extreme example, where Young (1995) finds that TFP-growth only

4 Data and method

I use OLS with Panel Corrected Standard Errors (PCSE), Random Effects (RE) and Fixed Effects (FE) to investigate whether regime type affects technological change. Measuring technological change is difficult (see e.g. Nelson 2005). The most common measure is TFP-growth. TFP is calculated as a residual, when economic growth stemming from changes in factor inputs like physical capital, human capital and labor are subtracted from total growth (see e.g. Barro and Sala-i Martin 2004; Baier, Dwyer Jr. and Tamura 2002).

I utilize the extensive TFP-data from Baier, Dwyer and Tamura (2006), also described in Baier, Dwyer Jr. and Tamura (2002) covering 145 countries. They also provide very extensive time series, with 24 countries having time series for more than 100 years. The TFP-data are estimated with uneven intervals, approximately averaging a data point every tenth year for most countries.[7] I interpolate these series, assuming constant TFP-growth rates within periods, to get estimates of TFP-growth on an annual basis. I use both the interpolated annual data, and the periodic observations given by Baier, Dwyer and Tamura (2006) in different analyses below, to check the results' robustness.

There are several problems with TFP as a measure of technology-induced growth. First, TFP responds to any type of economic shock, for example under-utilization of capacity in a recession or profit windfalls from oil-price hikes. Second, TFP is a theoretical construct based on a particular macro-production function, and is therefore reliant on the assumptions underlying the chosen model (see Rodrik 1997). There are several potential biases in TFP

accounted for 0.2% annual growth in GDP between 1966 and 1990; a minuscule fraction of the 8.7% GDP growth rate. TFP-growth rates were higher in South Korea and Taiwan, but nevertheless accounted for only about one-fifth of economic growth. Although these authoritarian Asian Tigers have rightly been described as economic success stories, their successes cannot be attributed to extreme improvements in technological efficiency. These authoritarian success-stories do therefore not threaten the validity of the model proposed above.

[7] These authors use data from multiple sources, and calculate TFP using income per worker rather than per person. They assume Hicks-neutral technology and a capital share of 1/3. For a closer description of these data and the underlying assumptions, see Baier, Dwyer Jr. and Tamura (2002).

(see e.g. Verspagen 2005). Among others, it may be underestimated since investment and work effort likely increase when technology level, and thereby returns to inputs (wages and interest), increase. If so, technological change is a cause of input accumulation. However, growth will be assigned to input accumulation in the growth accounting. Nevertheless, there is no good reason why such biases should critically influence the relationship between democracy and TFP. TFP-data are also troubled by unsystematic measurement error, especially for the older data, where both GDP, capital stocks and human capital stock estimates are based on thin data material (see e.g. Maddison 2006; Baier, Dwyer and Tamura 2006). If these errors are unsystematic, they do not bias coefficients but should only increase the regression's standard errors, thereby making it harder to find significant results. Therefore, the woolly quality of the older TFP-data do not cast serious doubts on the validity of the findings below.

A tricky issue related to measuring the impact of technological change on economic growth, is the time lag (see e.g. Verspagen 2005; Crafts 2003). When it comes to economic growth benefits from General Purpose Technologies, Craft argues that "[T]he lag before a GPT has its full effect on productivity is measured in decades not years." (2003:19). There is also a time lag from political institutions and policies on innovation and idea diffusion: First, there might be a lag from the adoption of or adjustment of an institutional framework to the diffusion of ideas *into* the nation. Second, it takes time before ideas diffuse widely *within* the national economy. Using patent citation data, Caballero and Jaffe (1993) estimate the diffusion lag of ideas between US firms to be on average between one and two years, whereas "Mansfield, Schwartz, and Wagner (1981) found that 60 percent of the patented innovations they studied were imitated within 4 years" (Segerstrom 1991, :808). Third, it takes time before economic actors can efficiently utilize new ideas in actual production. This needs to be taken into account in the empirical analysis. Although no concrete model exists that would allow us to better guess the total time lag, I use two different models that operate with five- and ten year lags.

One regime-proxy which can be used for testing the relationship modeled above is the "Civil Liberties" (CL) index by Freedom House, which explicitly taps into protection of civil liberties like freedom of speech, media and assembly.[8] 7 is given to the countries with the worst protection of civil liberties, and 1 is given to those with the strongest protection. However, the CL only has data back to 1972, which yields relatively few observations. I therefore mainly rely on the Polity-index (PI), which measures degree of democracy operationalized according to participation and competition in elections and checks on the executive (Marshall and Keith 2002). The PI goes from -10 (least democratic) to 10 (most democratic). Although the PI does not explicitly capture civil liberties, the correlation between these two indexes (1972-2003) was -.86. The PI has data going back to 1800, and therefore allows us to extend the time series dramatically.

Technological change is not only a function of regime type. Therefore, several other factors need to be controlled for. The pre-existing level of TFP, is likely important to TFP-growth. Idea-gaps (Romer 1993) may create convergence effects analogous to those for capital stocks (Barro and Sala-i Martin 2004). Moreover, level of population may impact on technological change (Romer 1990). Technological diffusion and creation may also be hampered when there is political instability. I therefore control for log of regime duration from Polity IV. Moreover, geographic factors may affect TFP-growth (Hall and Jones 1999). I thus control for absolute latitude. As economic openness also may impact positively on idea diffusion, I control for the Frankel-Romer trade instrument. Both this instrument and the latitude data are taken from Hall and Jones (1999). I also control for the ethnic fractionalization index from Alesina et al. (2003). Easterly and Levine (1997) find that ethnic fractionalization has an important effect on economic growth in general, and difficulties of

[8] One problem with using CL, indicated by the model above, is that dictators adjust civil liberties partly as a response to for example global technology growth. This makes CL endogenous. This is not the case for the Polity-index.

solving collective action problems and social and lingual barriers may reduce technology diffusion in fractionalized societies. I also add region- and decade dummies to control for geographic- and time-specific effects, since both the relative frequency of democracy and the rate of TFP-growth may vary spatially and temporally due to exogenous reasons. The Fixed Effects analysis controls for country-specific effects, and thus only investigates the effect from regime type on TFP-growth based on within-nation variation. This reduces the probability of omitted variable bias.

5 Empirical results

I first run OLS with PCSE (see Beck and Katz 1995), which takes into account heterogeneous standard errors and contemporaneous correlation between panels, and AR(1) autocorrelation within panels. The first models utilize the interpolated data on TFP-growth. Table 1 shows the OLS with PCSE results: The Politylong5 and Politylong10 models show estimates from models using the PI with some time-series going back to the 19th century, with 5 and 10 year lags respectively. The Polityshort models are restricted to the time period from 1972. So are the FHICL models, but these models use CL as regime measure. As we see from Table 1, there is generally very good support for Proposition 1: Dictatorial governments reduce TFP-growth. In all models, the regime coefficient has the expected sign. The models based on the long time-series yield the strongest results, with both models showing significant positive effects from democracy (at least 5%-level). However, also the models with shorter time-series yield a significant, positive effect from democracy, independent of regime-measure, when the 10-year lag is used. However, when using the 5-year lag, the coefficients are non-significant at conventional levels.

The size of the estimated effects are quite substantial: With the exception of one estimate, the models' estimates indicate an effect from going from most dictatorial to most democratic from about 0.4 to 0.7 percent extra TFP-growth per year. If democracies in addition grow more because they enhance human capital accumulation (see e.g. Tavares and Wacziarg 2001; Baum and Lake 2003), democracies have a quite substantial growth advantage on dictatorships because of knowledge-related factors. Dictatorships may hoard physical capital investment better (Tavares and Wacziarg 2001; Przeworski and Limongi 1993), but in the long run knowledge matters, and democracies prosper.

However, there may be country-specific characteristics biasing the results above. I therefore run RE and FE to check the results' robustness. Indeed, the RE results shown in Figure 2 indicate an even stronger effect from democracy on technological change. All regime coefficients, except in one model (CL with 5-year lag), are statistically significant at the 1%-level, with absolute t-values from 3.15 to 6.48. Moreover, the sizes of the coefficients are larger than in Table 1, indicating an effect from full democracy on TFP-growth from 0.8 to 1.7 percent per year. Also the results from the FE models, shown in Table 3, are very strong. Even when we utilize only within-nation variation, four of six models find a significant effect from democracy on TFP-growth at the 1%-level, and one model finds a coefficient almost significant at the 5%-level. The estimates are quite large, indicating a TFP-effect from full democracy of about 0.6 to 1.2 percent extra annual growth. When taking a long view, say 70 years, a country with a 1 percent higher TFP-growth than another otherwise equal country, would be twice as rich as the other at the end of the period, if starting out equally rich.

The interpolation conducted on the sample above may be problematic, as it expands the number of data points and introduces additional measurement error. I utilize another specification to further check the robustness of the results. I calculate the average annual TFP-growth rates for the periods between time-points where Baier, Dwyer and Tamura (2006) have provided TFP-estimates. Some of these periods are as short as four years, and I include periods of up to twenty years. However, the large majority of periods are ten years in duration (581 out of 795, an additional 82 periods are either nine or 11 years, and only

Table 1: OLS with PCSE models on interpolated data. Time dummies and constant omitted from table

Model Variable	Polityl5 b/(t)	Polityl10 b/(t)	Politys5 b/(t)	Politys10 b/(t)	FHICLs5 b/(t)	FHICLs10 b/(t)
Polity	0.036***	0.022**	0.021	0.033**		
	(4.30)	(2.34)	(1.57)	(2.15)		
FHICL					-0.029	-0.122***
					(-0.68)	(-2.99)
LN TFP	-2.387***	-1.998***	-2.138***	-1.961***	-2.033**	-2.053***
	(-5.22)	(-5.03)	(-2.81)	(-3.24)	(-2.56)	(-3.46)
LN population	-0.447***	-0.225**	-0.594***	-0.179	-0.502**	-0.191
	(-3.65)	(-2.37)	(-2.69)	(-1.42)	(-2.35)	(-1.37)
LN regime duration	-0.004	-0.053**	0.011	-0.041	-0.005	-0.061*
	(-0.15)	(-2.09)	(0.25)	(-1.00)	(-0.10)	(-1.72)
Ethnic fraction.	-1.198**	-1.320**	-3.290***	-3.534**	-3.823***	-3.504*
	(-2.18)	(-2.08)	(-3.14)	(-1.97)	(-3.33)	(-1.92)
LN Frankel-Romer	-0.711***	-0.235	-1.134**	-0.658**	-0.976*	-0.667**
	(-3.09)	(-1.20)	(-2.23)	(-2.26)	(-1.93)	(-2.36)
Latitude	0.006	0.003	0.009	-0.003	0.009	-0.003
	(1.28)	(0.68)	(1.43)	(-0.36)	(1.25)	(-0.31)
E.Eur.+Soviet rep.	-0.838*	-0.859*	-1.251	-2.554***	-1.313	-2.491***
	(-1.79)	(-1.92)	(-1.44)	(-5.84)	(-1.44)	(-6.05)
Africa SS	-2.749***	-2.307***	-2.001**	-2.246***	-1.835**	-2.495***
	(-4.83)	(-4.61)	(-2.45)	(-3.38)	(-2.44)	(-3.37)
Asia-Pacific	-1.527***	-1.082***	-1.072*	-1.947***	-1.009*	-2.012***
	(-3.43)	(-2.67)	(-1.93)	(-3.39)	(-1.78)	(-3.34)
Middle East+N.A.	0.313	-0.293	-0.463	-1.577***	-0.997*	-1.568***
	(0.73)	(-0.77)	(-0.79)	(-5.69)	(-1.82)	(-6.83)
Latin America	-1.259**	-0.975*	-1.880*	-2.880***	-1.705*	-2.940***
	(-2.35)	(-1.92)	(-1.94)	(-5.22)	(-1.84)	(-4.85)
N	6407	5860	2629	2082	2638	2076

Table 2: Random Effects (robust standard errors) results. Time dummies and constant omitted from table

Model Variable	Polityl5 b/(t)	Polityl10 b/(t)	Politys5 b/(t)	Politys10 b/(t)	FHICLs5 b/(t)	FHICLs10 b/(t)
Polity	0.040***	0.040***	0.044***	0.083***		
	(6.26)	(6.48)	(3.15)	(5.73)		
FHICL					-0.067	-0.240***
					(-1.18)	(-3.84)
LN TFP	-3.330***	-4.158***	-2.907***	-3.219***	-2.916***	-3.399***
	(-18.25)	(-23.40)	(-6.98)	(-6.38)	(-7.02)	(-6.70)
LN population	-1.568***	-1.724***	-0.958***	-0.618**	-0.883***	-0.567**
	(-14.17)	(-14.03)	(-4.86)	(-2.47)	(-4.38)	(-2.22)
LN regime duration	-0.124***	-0.201***	-0.068	-0.192***	-0.069	-0.239***
	(-4.06)	(-7.21)	(-1.02)	(-3.01)	(-1.11)	(-3.90)
Ethnic fraction.	-1.585**	-1.146	-3.331***	-3.332***	-3.344***	-3.321***
	(-2.24)	(-1.25)	(-3.73)	(-3.08)	(-3.74)	(-3.10)
LN Frankel-Romer	-2.440***	-2.623***	-1.573***	-1.047**	-1.431***	-0.929**
	(-9.50)	(-8.30)	(-4.19)	(-2.30)	(-3.74)	(-2.03)
Latitude	0.024***	0.025**	0.015	0.007	0.012	0.005
	(3.06)	(2.33)	(1.58)	(0.57)	(1.30)	(0.38)
E.Eur.+Soviet rep.	-1.253*	-1.902**	-1.897*	-2.119	-2.276**	-2.534**
	(-1.78)	(-2.00)	(-1.92)	(-1.63)	(-2.29)	(-2.00)
Africa SS	-3.779***	-4.838***	-2.648***	-2.835***	-3.057***	-3.299***
	(-6.02)	(-6.16)	(-3.32)	(-3.13)	(-3.94)	(-3.80)
Asia-Pacific	-1.835***	-2.531***	-1.391**	-1.947***	-1.684***	-2.279***
	(-3.85)	(-4.11)	(-2.39)	(-2.99)	(-2.92)	(-3.56)
Middle East+N.A.	-0.160	0.147	-0.590	-0.155	-1.009*	-0.541
	(-0.30)	(0.23)	(-1.00)	(-0.23)	(-1.75)	(-0.83)
Latin America	-2.724***	-3.153***	-2.817***	-2.904***	-3.021***	-3.245***
	(-5.30)	(-4.68)	(-5.02)	(-4.47)	(-5.52)	(-5.17)
N	6407	5860	2629	2082	2638	2076

Table 3: Fixed Effects (robust standard errors). Time dummies and constant omitted from table

Model Variable	Polityl5 b/(t)	Polityl10 b/(t)	Politys5 b/(t)	Politys10 b/(t)	FHICLs5 b/(t)	FHICLs10 b/(t)
Polity	0.036***	0.037***	0.030*	0.074***		
	(5.46)	(5.93)	(1.92)	(4.65)		
FHICL					-0.014	-0.198***
					(-0.23)	(-2.98)
LN TFP	-4.114***	-4.734***	-5.209***	-4.705***	-5.107***	-5.014***
	(-20.86)	(-27.55)	(-8.32)	(-7.31)	(-8.43)	(-7.79)
LN population	-2.610***	-2.423***	-5.005***	-2.331***	-4.687***	-2.260***
	(-17.88)	(-17.13)	(-8.36)	(-3.54)	(-7.91)	(-3.41)
LN regime duration	-0.137***	-0.210***	-0.057	-0.179***	-0.038	-0.222***
	(-4.51)	(-7.42)	(-0.80)	(-2.60)	(-0.58)	(-3.38)
N	6407	5860	2629	2082	2638	2076

17 are above 15 years). One period counts as one observation. For the control variables, I use the values at the start of the time period as proxies. However, for political regime, I construct a variable that takes the average of the PI over the five years prior to the period and all years within the period, except the five latest years, in order to take into account the lag of the effect on TFP-growth.[9]

According to the result from Table 4, and in accordance with the results above, democracy enhances TFP-growth. Independent of whether we control for country-fixed effects or not, the effect from democracy is statistically significant at conventional levels. To be more precise, it is almost significant at the 5%-level in the FE model, with a t-value of 1.96, and it is significant at the 1%-level in the OLS with PCSE and RE models. The point estimates are about equal to those obtained above, although a bit higher: A change from brutal dictatorship to full democracy over the period increases annual TFP-growth with between 1.0 and 1.4 percent. Of course, we can only strictly say the effect is significantly positive. But, if we are to believe the point-estimates, the effect is also quite large.

[9]There are to few observations on each panel on CL to run any meaningful panel analysis with this measure.

Table 4: Periodic observations, full sample. Time dummies and constant omitted from table

Technique Variable	OLSPCSE b/(t)	RE b/(t)	FE b/(t)
Sum Polity	0.067***	0.068***	0.049*
	(2.73)	(3.42)	(1.96)
LN TFP	-1.745***	-1.927***	-4.790***
	(-3.67)	(-4.76)	(-8.07)
Ln population	-0.075	-0.174	-2.796***
	(-0.84)	(-1.23)	(-5.74)
Ln regime duration	-0.043	-0.054	-0.078
	(-0.57)	(-0.63)	(-0.79)
Ethnic fraction.	-1.435	-1.606**	
	(-1.23)	(-2.51)	
LN Frankel-Romer	-0.186	-0.319	
	(-0.90)	(-1.19)	
Latitude	-0.002	-0.001	
	(-0.31)	(-0.12)	
E.Eur.+Soviet rep.	-0.299	-0.387	
	(-0.53)	(-0.54)	
Africa SS	-1.189**	-1.353*	
	(-2.37)	(-1.94)	
Asia-Pacific	-1.098**	-1.165**	
	(-2.47)	(-2.05)	
Middle East+N.A.	0.071	0.093	
	(0.13)	(0.17)	
Latin America	-0.812*	-1.000**	
	(-1.75)	(-1.97)	
N	594	594	594

It was argued above that dictatorships with high institutional capacity could mitigate democracy's technology advantages by better separating between politically dangerous and economically productive information. We test this hypothesis by constructing an interaction term between CL and a proxy for institutional capacity, ICRG's Bureaucratic Quality Index (BQI). On the BQI, "high points are given to countries where the bureaucracy has the strength and expertise to govern without drastic changes in policy or interruptions in government services... [and where] the bureaucracy tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training" (ICRG N.d.). The time series unfortunately start in 1984, and several countries lack data. The lowest score is 0 and the highest is 4, with differentiation allowed also on the decimals.

A strict interpretation of the theoretical model would lead us to include only the democracy measure and the interaction term, but not a linear BQI term, as institutional capacity only affects technological change in dictatorships in the model. When testing the models with interpolated data above (but now including an interaction term), we find some evidence of Proposition 7. In the OLS with PCSE models, both when using 5- and 10 year lags, the linear CL-coefficient and the interaction term are both significant at the 1%-level, and with expected signs. The estimates even indicate that dictatorships with high institutional capacity outperform democracies in terms of TFP-growth. However, this finding is not robust to choice of estimation technique. The interaction term is insignificant, even at the 10%-level, when utilizing RE and FE. The robustness of the OLS with PCSE-finding is further aggravated when we alter the econometric models by incorporating a linear BQI term. Although the theoretical model above did not include any linear effect from institutional capacity, there may be non-modeled mechanisms that allow also democracies with high institutional capacity to achieve higher TFP-growth. Indeed, the OLS with PCSE model with a 10-year lag, show significant coefficients for both the CL (5%-level), the BQI (10%-level) and the interaction term (5%-level), with expected signs. However, the RE model with 5-year time lag has a significant interaction term at the 10%-level with the "wrong" sign. Moreover, the other models find no significant interaction term. Thus, there is only weak evidence for the postulated relationship in Proposition 7. We should however remember that we utilize data from a very short period of time here.

6 Conclusion

This paper focused on how democracy and dictatorship affect the most important determinant of long-run economic growth, technological change. In dictatorships, diffusion of economically relevant ideas and technologies is slowed down because dictators manipulate civil liberties and promote policies that inhibit idea diffusion. Although dictators in an optimal world would have wanted to promote technological change to increase their own personal consumption, dictators in practice have to trade off increased growth against increased possibility of being thrown out of office. Dictators are unable to perfectly separate politically dangerous from economic efficiency-enhancing information when setting their policies. The empirical results, based on a very extensive data material, generally corroborated this hypothesis. Democracies have higher TFP-growth rates, indicating more rapid technological change. In the long run, therefore, democracies should prosper more than dictatorships. The effects from physical capital investment on growth, where dictatorships often do better (Tavares and Wacziarg 2001; Przeworski and Limongi 1993), are probably only transitional (Solow 1956). The effect from technological change on growth is not.

A second hypothesis, that dictatorships with high-quality institutional apparatuses could mitigate democracy's technology advantage, found far less empirical support. Nevertheless, better and more extensive TFP-data or data for other proxies of technological change, could in the future allow us to replicate the hypotheses tests. Future research could also further investigate the regime type-technological change relationship by testing Propositions 3 and

4 derived from this paper's model, indicating that dictatorships reduce their restrictions on civil liberties in times of rapid, global technological advances and that dictators with a secure grip on power allow for more technological change.

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